Application

For

United States Non-Provisional Utility Patent

Title:

AN ARRAY OF OPTICAL COMPONENTS ALIGNED TO AN ARRAY OF GRATING COUPLERS

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional application No. 60/389,961 filed June 19, 2002.

FIELD OF THE INVENTION

[0002] The present invention relates to an apparatus and method for facilitating the connection of integrated optical circuits to external optical components and devices.

BACKGROUND OF THE INVENTION

[0003] Grating couplers are a promising technology for coupling light between integrated optical elements and external components or devices. Grating couplers have advantages for use as optical input and output ports to optical or optoelectronic processing elements. Grating couplers are typically formed from lithographic techniques that create extremely precise positioning of grating couplers to other devices formed on the same substrate. It is not uncommon for current photolithography equipment to place elements with respect to one another with alignment precision on the order of 1 – 10 nm. For many optical devices, this type of precision far exceeds the tolerance requirements for accurate optical alignment. It is

desirable to leverage this accuracy to enable cost-effective, parallel alignment of optical devices to the precisely located grating couplers.

SUMMARY OF THE INVENTION

[0004] For the purposes of this invention, an array of elements will refer to two or more similar optical devices that are spaced with known positions with respect to one another in a plane and held rigidly in place with a substrate or other mechanical construction. An array containing multiple devices need not be evenly spaced in any dimension, although the relative positions are best well known and controlled in a high-volume assembly environment. However, the best mode is often to create an array of evenly spaced devices.

[0005] Connecting an optical fiber to an optical grating coupler is well known in the art. Connecting an array of optical fibers to an array of grating couplers has not been known in the art. Connecting any optical device, such as a photodetector to a grating coupler by the flip-chip method has not been known in the art. Many optical devices that would be advantageously coupled to grating couplers are also formed from lithographic techniques. Examples include vertical cavity surface emitting lasers (VCSELs), Fabry-Perot lasers, diffractive elements, fiber V-groove substrates, and photodetectors.

[0006] Furthermore, during the construction of optical devices, including grating couplers, other features, such as bond pads and fiducials are also conveniently formed with high relative precision to the optical element. Examples are the bond pads on a photodetector or laser die. Similar features can be placed on a substrate containing grating couplers.

[0007] It is desirable to use these fiducials and bond pads to facilitate flip-chip assembly of optical devices over optoelectronic circuits containing grating couplers. The flip-chipping process typically uses a solder, such as the commonly used C4, or gold balls in what is commonly referred to as gold stud bumping. This style of approach has the advantage of also providing electrical contact between the substrate containing the grating couplers, and the optical device which is affixed on top. When electrical contact is not needed, these approaches are still valid, however additional flexibility, such as attachment via epoxy or other mechanical bonding technique is often acceptable.

[0008] It is also possible to grow, deposit or form optical devices over a substrate that contains a grating coupler array via techniques involving chemical vapor deposition, physical vapor deposition, epitaxial deposition, sputtering, etching, photolithography, spin coating, screen printing, injection molding, stamping, or other physical processing techniques. A number of these techniques, such as CVD and epitaxial growth can be self-aligned to the grating couplers. Photolithographic techniques allow the processing and formation of optical devices over grating couplers with high precision due to the common practice of using accurate alignment marks and specialized photolithographic equipment capable of the appropriate accuracy.

[0009] This invention is particularly useful when the optical devices are also fabricated with photolithographic techniques of adequate precision to allow simultaneous optical alignment of all elements of the array with the array of grating couplers. An example would be an array of photodetectors fabricated on a substrate formed from a III-IV compound. These photodetectors are lithographically defined, and have bonding pads that are also lithographically defined and aligned with respect to the photodetector.

The lithographic process easily lends itself to the construction of an array of these devices that is matched in dimension to the grating coupler array, and thus when these two arrays are flip chipped together, it is possible to ensure simultaneous alignment of all of the devices.

[0010] During the flip-chipping process, fiducials and a number of active and passive alignment techniques can be used to align only a small number of the devices, logically the first and last elements of a linear array, and ensure that all other devices are aligned as well. It does not have to the first and last elements, but in general the farther apart in the array that the small number of chosen devices are, the better the alignment will be. In certain applications it may suffice that a single element, or two elements in the center of an array are aligned.

[0011] Examples of benefits derived from flip-chipping an array of optical elements such as VCSELs or photodetectors over a substrate are when the substrate contains both the optical circuit that connects to the optical element, and the electrical circuit that connects to the optical element. An example of an implementation would be a system to generate an electrical signal from optical signals in an array of waveguides in a substrate. A grating coupler array can direct the optical signals to a photodetector array that is flip-chipped over the grating coupler array. The flip-chipping process can simultaneously allow electrical connections to transimpedance amplifiers or other circuitry that are used to process the signal from the photodetectors. The present invention has many advantageous implementations involving all types of lasers, optical amplifiers, and photodetectors, although a number of other devices could be used in a similar manner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1 is a top view of a SOI substrate upon which is fabricated an array of grating couplers and metal pads.

[0013] Figure 2 is a view of an array of optical devices, such as a photodetectors or VCSELs.

[0014] Figure 3 is the cross sectional view of an optical device that has been flip-chipped over the grating coupler.

DETAILED DESCRIPTION

[0015] Figure 1 shows grating couplers 103 arranged in a linear array 100 disposed on a substrate 101 that also contains an optoelectronic device 102. This embodiment demonstrates a linear array of grating couplers, although an array of any shape and orientation may be used as well. In this embodiment there are metal pads 104 that serve the function of providing mechanical attachment and alignment as well as electrical connection via leads 107 to the optoelectronic device 102. Optical connection between the optoelectronic device 102 and the grating couplers 103 is achieved with an optical waveguide 106.

[0016] In addition, fiducials 105 are placed on the substrate to facilitate alignment of the optical devices to the grating coupler array. In this embodiment, fiducials 105 are placed that facilitate the flip-chip attachment of an array of optical elements 200 which are formed on a second substrate 201 as shown in Figure 2.

[0017] Figure 2 shows the optical elements 200, in this case representative of photodetectors or VCSELs, aligned in the corresponding

linear array. Metal pads 202 are contained on the second substrate 201, and some are shown that will provide only mechanical attachment, while some also serve as the electrical connection to the optical elements 200 via electrical leads 204.

[0018] Figure 3 shows a cross-section of the final assembly of the flip-chipped structure 300 where the substrate containing optical devices 304 in an optical array 302, is electrically and mechanically attached to the substrate containing the array of grating couplers 301 via a gold or C4 ball 307. The ball directly connects a metal pad 306 on the optical device substrate 302 to a metal pad 305 on the grating coupler array substrate 301. Optical connection between the substrates is achieved by the grating coupler 303 and an input optical path 309 and/or an output optical path 308. Note that the optical paths also extend into the waveguide 310 which is also shown in cross-section here.

[0019] While these drawings show a preferred embodiment of one example of an array of grating couplers aligned to an array of optical devices, note that many other implementations can be conceived and implemented based on the concepts elaborated herein.